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Searches for charged Higgs bosons in ATLAS

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Summary. — The presented analyses were performed by the Higgs to Complex States Working Group of the ATLAS Collaboration, using pp collisions data taken by the ATLAS detector in 2010 and 2011 at the LHC. An outline of the analysis and the result of the charged Higgs in the $c\bar{s}$ final state, which uses kinematic fitting algorithms, was presented. Upper limits on $\mathcal{B}(t \rightarrow bH^+) \times \mathcal{B}(H^+ \rightarrow c\bar{s}) = 0.25$ to 0.14 for $m_{H^\pm} = 90$ to 130 GeV have been derived. In the second part the charged Higgs in the hadronic τ final state analysis, which utilizes different techniques to estimate all background contributions from the data, was summarized. Values of the product of branching ratios $\mathcal{B}(t \rightarrow bH^+) \times \mathcal{B}(H^+ \rightarrow \tau + \nu)$, larger than 0.03 to 0.10 have been excluded in the H^\pm mass range 90 to 160 GeV.

PACS 14.65.Ha – Top quarks.

1. – Introduction

The charged Higgs boson is predicted by many extended Higgs scenarios, such as models containing Higgs triplets and Two-Higgs-Doublet Models (2HDM). The observation of charged Higgs bosons, H^\pm , would indicate physics beyond the Standard Model (SM). Both analyses presented here [1] consider the type-II 2HDM, which is also the Higgs sector of the Minimal Supersymmetric Standard Model (MSSM). For charged Higgs boson masses, m_{H^\pm} , smaller than the top quark mass, m_t , the dominant production mode at the LHC for H^\pm is through top quark decay via $t \rightarrow bH^+$. The dominant source of top quarks at the LHC is $t\bar{t}$ production (fig. 1).

2. – The $c\bar{s}$ + jets final state

The goal of this analysis is to search for $H^+ \rightarrow c\bar{s}$ decays. In the absence of a signal signature in data, exclusion limits for the top decay branching ratio to a light charged Higgs boson $\mathcal{B}(t \rightarrow bH^+) \times \mathcal{B}(H^+ \rightarrow c\bar{s})$ are derived from early ATLAS data. A kinematic fit improves the sensitivity for a possible signal and allows to set very good limits, using only 35 pb^{-1} .

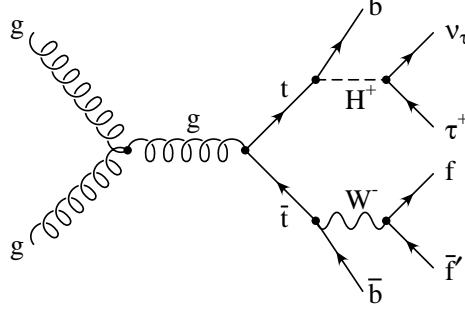


Fig. 1. – Example for a leading-order Feynman diagram for the production of a charged Higgs boson through gluon fusion in $t\bar{t}$ decays.

2.1. The kinematic fit. – In lepton plus four jets events, the two jets originating from decays of H^+ need to be identified in order to reconstruct the mass of H^+ candidates. A kinematic fitter [2] is used to identify and reconstruct the mass of dijets from W/H^+ candidates, by fully reconstructing the $t\bar{t}$ system. In the kinematic fitter, the lepton, the missing transverse energy, E_T^{miss} , (from the neutrino), and four jets are assigned to the decay partons from the $t\bar{t}$ system.

2.2. Result and limits. – The sensitivity of the analysis presented in [4] is comparable to the limits obtained at the Tevatron, where datasets with more than twenty-five times the integrated luminosity were used. The limits are shown in fig. 2 where the extracted limits are compared with the previous limits from the Tevatron [2,3].

3. – The τ + jets final state

The goal of this analysis is to search for the light charged Higgs bosons in the decay channel $H^+ \rightarrow \tau + \nu$, all the backgrounds of the selection are estimated from data using data-driven techniques [5]. Only a selection of the methods applied is presented below. In absence of a significant signal, limits on the branching ratio of $\mathcal{B}(t \rightarrow bH^+) \times \mathcal{B}(H^+ \rightarrow \tau + \nu)$ are derived.

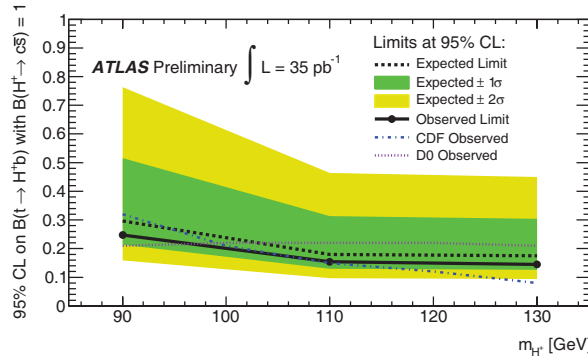


Fig. 2. – The extracted 95% CL upper limits on $\mathcal{B}(t \rightarrow bH^+)$ from the ATLAS data are compared with the expected results and results from the Tevatron. These results assume $\mathcal{B}(H^+ \rightarrow c\bar{s}) = 100\%$. The ATLAS limits shown are calculated using the CL_s limit setting procedure.

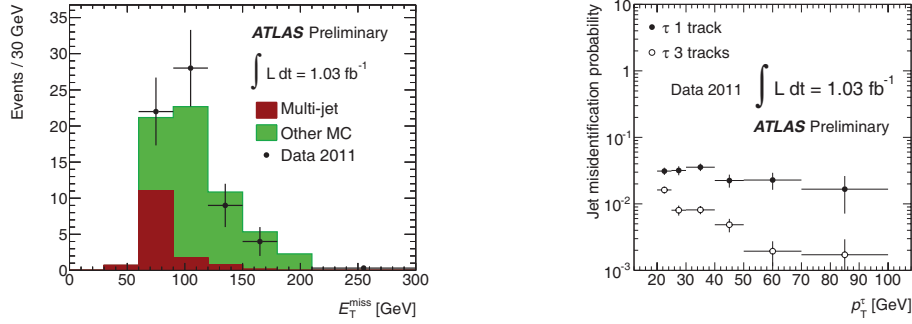


Fig. 3. – Left: multi-jet estimate: A fit to the E_T^{miss} distribution in data after all selection cuts using two shapes (one for the multi-jet model, and one for all other background processes, dominated by $t\bar{t}$ and W +jets) is shown. The multi-jet fraction estimated after all selection cuts is $(23 \pm 10)\%$. Right: jet $\rightarrow \tau$ misidentification probabilities measured from γ +jet events for 1-track and 3-track tight likelihood based τ identification, *versus* p_T , using an integrated luminosity of 1.03 fb^{-1} are shown.

3.1. Multi-jet background estimation and jet-to- τ misidentification probability. – The multi-jet background is estimated by fitting its E_T^{miss} shape to data (fig. 3 (left)). In order to study this shape in a data-driven way, a control region is defined by inverting the τ identification and b -tagging requirements. A measurement of the probability for a jet to be misidentified as a hadronically decaying τ lepton is used to predict the yield of jet-to- τ misidentification events (fig. 3 (right)) from the most important SM backgrounds with intrinsic E_T^{miss} .

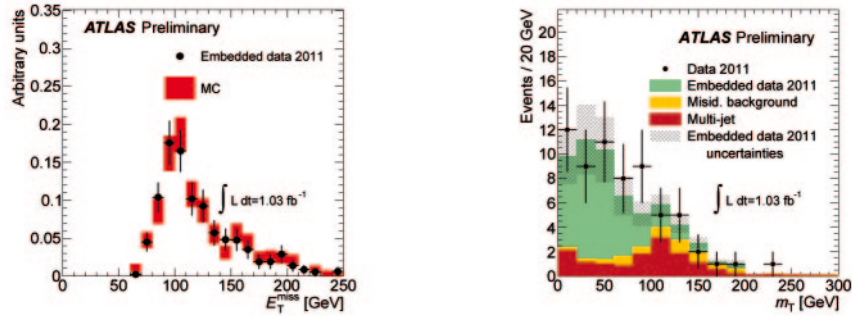


Fig. 4. – Left: The embedded data E_T^{miss} shape, normalized to unit area, is compared to $t\bar{t}$ simulation after applying the H^+ selection (shaded area indicates the statistical uncertainties on the MC simulation). Right: Comparison of the m_T shape for embedded events *versus* collision data. The prediction using the embedding method is stacked on top of the expected backgrounds with objects misidentified as τ jets: MC expectation for $t\bar{t}$ and electroweak processes, and the data-driven estimate for multi-jet events. The comparison is done after the H^+ event selection and after normalizing the m_T distribution of embedded events to the data distribution in the range 0–40 GeV (gray area indicates the statistical and systematic uncertainties of the embedding method estimate).

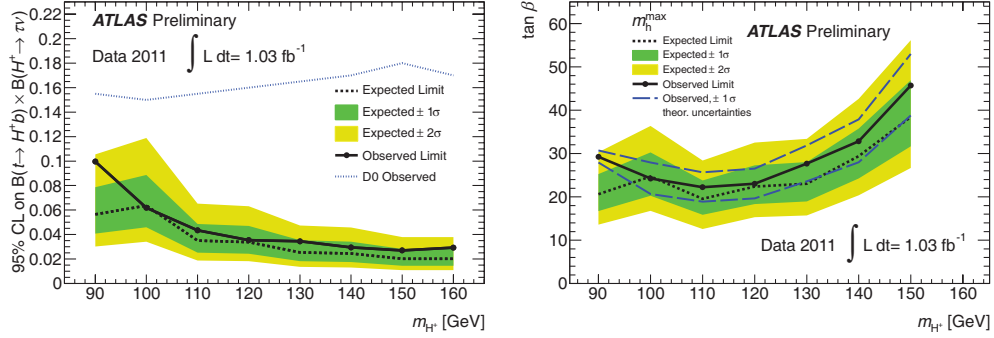


Fig. 5. – Left: Expected and observed 95% CL exclusion limits for charged Higgs boson production from top quark decays as a function of m_{H^+} in terms of $B(t \rightarrow H^+ b) \times B(H^+ \rightarrow \tau^+ \nu)$. For comparison, the best limit provided by the Tevatron experiments is shown [3]. Right: Limit for charged Higgs boson production from top quark decays in the m_{H^+} - $\tan \beta$ plane. Results are shown for the MSSM scenario m_h^{max} .

3.2. The embedding method. – The method consists of collecting a control sample of real $t\bar{t}$, single-top and W +jets events with a muon and replacing the detector signature of this muon with that of a simulated τ lepton. The reconstruction is re-applied to the new hybrid events which are then used to estimate the true- τ background of the selection (fig. 4). The whole event (except for the τ jet) is taken directly from data, including the underlying event and pile-up, missing energy, b quark jets and light quark jets.

3.3. Result and limits. – Using data-driven background estimates, no statistically significant excess of events is observed in 1.03 fb^{-1} of collision data. Exclusion limits are set on the branching ratio $t \rightarrow bH^+$ (fig. 5 (left)), and in the m_{H^+} - $\tan \beta$ plane (fig. 5 (right)), by rejecting the signal hypothesis at the 95% confidence level applying the CL_S procedure [6, 7]. A profile likelihood ratio [8] is used with the m_T distribution as the discriminating variable. The final limits are based on the asymptotic distribution of the test statistic [8].

REFERENCES

- [1] ATLAS COLLABORATION, *Searches for Light Charged Higgs Bosons in pp Collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS Experiment*, ATLAS-PHYS-SLIDE-2011-625 (2011).
- [2] AALTONEN T. *et al.* (CDF COLLABORATION), *Phys. Rev. A*, **103** (2009) 101803.
- [3] ABAZOV V. M. *et al.* (CDF COLLABORATION), *Phys. Lett. B*, **682** (2009) 278.
- [4] ATLAS COLLABORATION, *A Search for a light charged Higgs boson decaying to $c\bar{s}$ in pp collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS detector*, ATLAS-CONF-2011-094 (2011) <https://cdsweb.cern.ch/record/1367737>.
- [5] ATLAS COLLABORATION, *Search for Charged Higgs Bosons in the τ +jets Final State in $t\bar{t}$ Decays with 1.03 fb^{-1} of pp Collision Data Recorded at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS Experiment*, ATLAS-CONF-2011-138 (2011) <https://cdsweb.cern.ch/record/1383841>.
- [6] READ A. L., *J. Phys. G: Nucl. Part. Phys.*, **28** (2002) 10.
- [7] JUNK THOMAS, *Nucl. Instrum. Methods*, **434** (1999) 435.
- [8] COWAN GLEN, CRANMER KYLE, GROSS EILAM and VITELLS OFER, *Eur. Phys. J. C*, **71** (2011) 1554.